

## REVIEW ARTICLES

# Assessment of human influenza pandemic scenarios in Europe

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The response to the emergence of the 2009 influenza A(H1N1) pandemic was the result of a decade of pandemic planning, largely centred on the threat of an avian influenza A(H5N1) pandemic. Based on a literature review, this study aims to define a set of new pandemic scenarios that could be used in case of a future influenza pandemic. A total of 338 documents were identified using a searching strategy based on seven combinations of keywords. Eighty-three of these documents provided useful information on the 13 virus-related and health-system-related parameters initially considered for describing scenarios. Among these, four parameters were finally selected (clinical attack rate, case fatality rate, hospital admission rate, and intensive care admission rate) and four different levels of severity for each of them were set. The definition of six most likely scenarios results from the combination of four different levels of severity of the four final parameters (256 possible scenarios). Although it has some limitations, this approach allows for more flexible scenarios and hence it is far from the classic scenarios structure used for pandemic plans until 2009.

## Introduction

Before the 2009 influenza A(H1N1) pandemic, most European Union (EU) Member States had developed preparedness plans in order to timely respond to an eventual pandemic. Many of these plans involve explicit or implicit planning assumptions on what can be expected during a pandemic and on how a pandemic virus might behave [1].

The response to the emergence of the 2009 influenza A(H1N1) pandemic was the result of a decade of

pandemic planning, largely centred on the threat of an avian influenza A(H5N1) pandemic. However, the influenza A(H5N1) and the 2009 pandemic influenza A(H1N1) viruses have markedly different characteristics in terms of mortality among confirmed cases and human-to-human transmission [2,3]. Moreover, the 2009 pandemic influenza A(H1N1) virus caused illness that did not require hospitalisation in the vast majority of cases, and was a highly transmissible virus among humans spreading to several countries within days [3,4].

In this situation, the severity assessment applied during the 2009 influenza A(H1N1) pandemic using a variety of indicators leading to a qualitative assessment in three levels (i.e. mild, moderate and severe) was not specific enough to guide interventions [5,6].

After the pandemic, the International Health Regulations (IHR) Pandemic Review Committee encouraged the World Health Organization (WHO) to develop and utilise measures to assess the severity of every influenza epidemic by applying, evaluating and refining tools to measure severity every year [7]. WHO has recently developed a new document for Pandemic Influenza Risk Management [8].

The 2009 influenza pandemic highlighted the importance of quantitatively defining different scenarios; severity should be assessed as early as possible during a pandemic and continually re-assessed as the pandemic evolves and new information becomes available.

This work has been conducted in the frame of the European Commission project FLURESP (Cost-effectiveness assessment of European influenza human pandemic alert and response strategies) with the aim to define a set of scenarios to be used for a future pandemic planning ([www.fluresp.eu](http://www.fluresp.eu)).

## Methods

### Literature review and selection of parameters

The literature search was conducted by consulting Medline, restricting it to articles published until December 2011. Seven different sets of keywords were considered (Table 1).

A systematic selection procedure was conducted in two steps by two researchers independently. In the first step, the major topics of the articles were assessed by title and abstract. In this phase of the selection procedure, all articles reporting epidemiological data on influenza pandemics were included. In case of doubt on the article's relevant information, the article was included in the second selection step.

In the second step, the full text articles, previously selected, were assessed. These articles were included in the review if they reported at least one of the following 13 parameters: basic reproductive number ( $R_0$ ); clinical attack rate (CAR); age-specific CAR; case fatality rate (CFR); communicability/generation interval; modes of transmission; incubation period; timing and duration of pandemic; clinical consultation rate (CCR); hospital admission rate (HAR); intensive care admission rate (ICAR); work absenteeism; bed occupancy rate (BOR). If the articles included did not contain

information on at least one of the parameters listed above or if the study design was of low quality (e.g. small sample size, unclear definition of outcomes), they were excluded. Moreover, pertinent related citations were considered.

Of each article included in the review, the following data were recorded: year of the study, year of pandemic referring to, country, and described parameters.

International technical reports were obtained by consulting the websites of the European Centre for Disease Prevention and Control (ECDC) and WHO. Influenza pandemic preparedness plans for the European Union/European Economic Area (EU/EEA) countries were obtained from the ECDC website [9]. We also considered relevant studies based on mathematical modelling published in the literature but not retrieved through the search strategy.

Parameters collected through the literature review were subsequently discussed within the FLURESP Project by a panel of experts composed of collaborators from international (WHO and ECDC) and national public health organisations (from France, Italy, Spain and the United Kingdom) who selected the parameters to be used for defining scenarios.

### Definition of severity profiles and scenarios

For each of the selected parameters, four severity profiles were defined. In order to set the profiles, ranges of variability for each of the parameters were categorised into a four-group scale, according to a quartile distribution. We then adjusted the ranges for each of the four groups, according to the suggestions made by the panel of experts. Based on the possible combination of the four severity profiles of each of the four parameters, a set of scenarios were defined.

## Results

### Parameters selected

From the literature review we collected information on 13 parameters as potential candidates for defining the pandemic scenario. These parameters were divided into eight *virus-related* ( $R_0$ ; CAR; age-specific CAR; CFR; communicability/generation interval; modes of transmission; incubation period; timing and duration of pandemic) and five *health-system-related* (CCR; HAR; ICAR; work absenteeism; BOR).

The panel of experts was of the opinion that some of the parameters collected through the literature review were more relevant for mathematical modelling than for public health purposes, and others were considered less relevant for defining scenarios; consequently, all these were excluded:  $R_0$ ; age-specific CAR; communicability/generation interval; modes of transmission; incubation period; timing and duration of pandemic. For example,  $R_0$  (the average number of secondary infections produced by a single infected individual while

**TABLE 1**

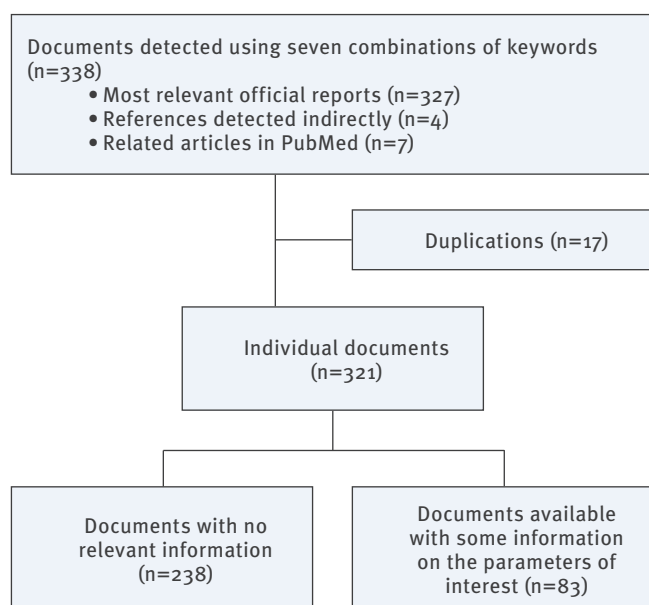
Sets of keywords used in searching scientific articles and number of articles retrieved for the study on pandemic influenza scenarios in Europe

Sets of keywords	Original articles	Reviews	Total
'Human influenza pandemic description'	20	6	26
'Influenza outbreak parameters estimation'	7	0	7
'Influenza scenario description'	2	0	2
'Influenza pandemic scenario'	88	15	103
'Influenza pandemic scenario description'	2	0	2
'Influenza pandemic parameter estimation'	3	0	3
'Influenza pandemic investigation'	148	22	170
<b>Total</b>	<b>270</b>	<b>43</b>	<b>313</b>

The search was restricted to articles published until December 2011.

**FIGURE 1**

Flowchart outlining the selection of documents for the study on pandemic influenza scenarios in Europe



The search was restricted to articles published until December 2011.

they are infectious, in an entirely susceptible population), incubation period, and the generation interval (defined as the mean duration between time of infection of a secondary infected individual and the time of infection of their primary infector), are measures of the degree of transmissibility of an infection and in combination might affect CAR. Age-specific CAR in most of the considered influenza pandemics were derived from studies conducted in small and selected communities not representative of the entire population, while the timing and duration of pandemic is expected to be from several weeks to a few months but will likely vary from country to country or within a single country. Therefore, these parameters were not considered in this study. Additionally, the contribution and clinical importance of potentially different modes of transmission of influenza are unknown and therefore were considered not relevant.

Thus, according to the opinion of the panel of experts, four parameters were selected to be used for defining scenarios for pandemic planning. The two *virus-related* parameters are listed below with their limitations:

- CAR, the proportion of the population with clinical symptoms over a specified period of time. Some individuals may not develop symptoms severe enough to be readily identified as acute respiratory infection (ARI) or influenza-like-illness (ILI). The measured CAR is thus not always the number of individuals who actually develop symptoms, and

may also include the number of individuals seeking healthcare.

- CFR, represented by the proportion of individuals who develop influenza symptoms, and die because of complications. The measured CFR could be affected by the laboratory confirmation that may be unavailable to validate the total number of cases. Moreover, the confirmation is likely biased to more severe cases. This results in an overestimation of the clinical severity of the disease, especially in case of people with underlying conditions that are at higher risk of death.

The *health-system-related* parameters deal with virulence (i.e. the ability of the virus to invade the tissues of the host and produce pathologic effects and complications) and impact (i.e. the effect on the healthcare sector) of the virus on the population. The most relevant *health-system-resource* utilisation parameters used to define pandemic scenarios are listed below with their limitations:

- HAR, represented by the proportion of population hospitalised for confirmed influenza independently from the presence of complications. This measure is strongly affected by how the healthcare systems in different countries are structured.
- ICAR, the proportion of hospitalisations for confirmed influenza that are treated in an intensive care unit (ICU) for influenza complications.

The ICAR could also be related to the level of virulence of the virus, since it is a proxy for the level of severity.

### Literature review

A total of 338 documents (including technical reports and scientific articles and reviews) were identified using our search strategy with the seven sets of keywords. Of these, 17 were duplicated articles and 238 showed no relevant information on the selected parameters (Figure 1). In conclusion, 83 articles and documents reporting information on the parameters listed above were considered for this study.

The year of publication of these documents ranges from 2003 to 2011 with more than half of the documents published between 2009 and 2010. When evaluating the performance of keywords' combinations selected, 26% (83/321) of the detected documents provided useful information on the parameters for defining scenarios. The largest number of documents was detected using three sets of keywords (293/321, 91%) (Table 1).

The keywords combination 'human influenza pandemic description' provided the highest proportion of useful documents (10/28, 36%).

The range estimates for the parameters derived from the 83 selected documents and their specific references are listed in Table 2.

**TABLE 2**

Range of values and references for the main parameters selected for the study on pandemic influenza scenarios in Europe

Parameters	Minimum	Maximum	References
Reproductive number ( $R_0$ )	0.99	3.75	[14, 34, 47–67]
Clinical attack rate (%)	0	50	[9,14,20,21–28,54,55,57,61,63,68,69,70–75,77–87]
Case fatality rate (%)	0	25	[9,14,20,27,31,42,54,57,59–62,66,70,71,73,75,82,83,88–98]
Generation interval (days)	1.6	4.1	[58,65,66]
Duration of infection (days)	1	21	[14,54,55,61,63]
Mode of transmission	NA	NA	[54,55,61,63,96,99,100]
Incubation period (days)	0.5	7	[14,20,26,33,48,54,63,66,69,76,99–102]
Pandemic duration (days)	0	180	[54,63,69,91,94,95,103]
Clinical consultation rate (%)	14	73	[24,52,54,55,61,76,104]
Hospital admission rate (%)	0	27.5	[24,31,32,42,52–55,61,63,65,69,70,71,75,77,82,88,90,91,94–96,105–107]
Intensive care admission rate (%)	0	34	[9,31,32,42,43,55,71,82,90,91,94–97]
Absenteeism (%)	0	40	[24,54,64,71,76,97,108]
Bed occupancy rate (%)	0	37	[109]

NA: not applicable.

Of the 83 relevant articles, 23 articles reported information on  $R_0$ , with values ranging from 0.99 to 3.75. Thirty-four reported data on CAR, whose values ranged widely between 0 and 50%, while eight documents provided some information on age-specific CAR. For the CFR, 30 articles showed a range between 0 and 25%. Only three articles dealt with the generation interval, whose range was 1.6–4.1 days. The duration of infectiousness, reported in five articles, ranged between one and 21 days. Only seven articles provided generic descriptions of possible modes of transmission: all of them reported the respiratory route by droplets of infected secretions and/or hand-face contact after touching a contaminated person or surface. The incubation period, described in 12 articles, ranged from 0.5 to seven days, while the pandemic duration varied from 0 to 180 days according to seven articles. Moving to health system resource utilisation parameters, CCR ranged from 14% to 73% (seven articles); HAR ranged from 0% to 27.5% (26 articles); ICAR ranged from 0% to 34% (13 articles); work absenteeism ranged from 0 to 40% (seven articles); and BOR was between 0% and 37% of total critical care bed capacity according to one article.

### Parameters collected from historical influenza pandemics

We also investigated parameters collected during the three significant influenza pandemics that occurred in the 20th century: 1918/19, 1957/58, and 1968/69 to 1969/70 (two waves) [5,10,11] (Table 3).

In some European countries (UK in particular) there were three waves associated with the 1918/19 pandemic [12]. In the UK, the wave structure of this pandemic is not well understood; the final 1919 wave may have been a separate pandemic of a different virus to the 1918 waves. The smallest of the waves was in July–August 1918, the largest second wave was from October 1918 to January 1919, and the third wave was from February to April 1919 [13]. Estimates of the national CAR vary in the UK, but suggest that nationally it was around 25% of the population (totalled over all waves). The highest CAR were observed in the young population. Estimates of the CFR are around 2%, relatively evenly spread across the population, though with an excess in young adults [12]. The 1957/58 pandemic had one wave. Estimates of the CAR vary, but suggest that nationally it was around 30% of the population.

**TABLE 3**

Relevant parameters collected in the four past influenza pandemics for the study on pandemic influenza scenarios in Europe

Season	Clinical attack rate (%)	Complication rate (%)	Hospital admission rate (%)	Case fatality rate (%)
1918/19	25	20	4	2–3
1957/58	30	2.7	<0.6	<0.2
1968/69–1969/70	35	2.7	<0.6	<0.2
2009/10	5	5–16 in at-risk groups <0.02–1 in healthy individuals	<0.02–1	<0.048 (influenza-like illness rate)



TABLE 4

Severity profile for the selected parameters, study on pandemic influenza scenarios in Europe

Parameters	Type of parameters	Severity profile (%)			
Clinical attack rate	Transmission	0–5	5–10	10–25	25–35
Case fatality rate	Virulence	0–0.01	0.01–0.05	0.05–0.8	0.8–2.5
Hospital admission rate	Use of medical resources	0–0.02	0.02–0.2	0.2–2	2–4
Intensive care admission rate		0–0.01	0.01–2.5	2.5–5	5–35

These severity profiles do not take into account any mitigation or control measures.

Estimates of the CFR are around 0.1–0.2%. These average figures mask the considerable variation by age, most deaths being in the older adult population. However, the highest number of cases was registered in the young individuals [14]. The 1968/69 pandemic came in two waves in Europe [15]. Estimates of the national CAR vary, but based on comparisons with the epidemic in the United States (US), it may have been around 35% of the population [12]. Estimates of the CFR are less than 0.2%. These average figures for mortality mask the considerable variation by age, again, with most deaths recorded in the older adult population.

Parameters collected from the 2009 influenza pandemic The recent influenza A(H1N1) pandemic in 2009/10 produced no major signal of excess deaths in the overall population [16], and most of the EU countries have reported data on those that have died from confirmed 2009 pandemic influenza A(H1N1) as a result of influenza A(H1N1) virus infection, but case ascertainment is unlikely to have been complete, and the true number is almost certainly higher [17–19].

Rates from the ILI surveillance systems across Europe showed that consultations were highest in the young. There was only one wave, except for the UK where two ‘waves’, one immediately following the other, were observed. There were high levels of background immunity among elderly.

In general, estimates of the CAR for the 2009 pandemic influenza A(H1N1) vary among countries: 0.01% in the central region of Portugal [20], 0.072% in Mexico [21], 18.3% in New Zealand [22], 30% in the Netherlands [23]. Across Europe the estimated CAR was 30% [24]. This variation reflects the different methods used to get the data: e.g. seroprevalence studies, epidemiological studies in different populations, mathematical models, etc. Other experiences in smaller groups of population provide additional results: 3.15% in a train in China [25], 4% in a primary school in China [26], 22% on a Peruvian Navy ship [27], 28.5% during an outbreak investigation in Nepal [28].

In the UK, figures used to track the epidemic suggest a CAR of 1–2% and modelling studies suggest that these estimates reflect only around 10% of those infected [29], which is consistent with the results of the

serological analysis of the first wave [30]. If only half of those infected were symptomatic, although possibly with very mild symptoms (as this is typical for influenza), the CAR would be around 5–10%. If so, estimates of the CFR are around 0.01% [31,32], but higher levels have been reported in the literature: up to 0.05% in the US [31], 0.1% in Spain [33], and 0.35% in Europe [24], 0.6% in Mexico [34]. In terms of age groups, mortality was spread evenly across the age groups although most cases were reported in the younger age groups.

#### Definition of severity profiles and scenarios

Table 4, shows the severity profile for each of the four selected parameters derived from the literature review and selected by the suggestions of the panel of experts.

With regard to CAR, the literature review reported data ranging from 0 to 50%. Nevertheless, since the maximum value of 50% refers to the extreme value reported during the 1889 ‘Russian’ pandemic [13,35–39], this value was excluded and, therefore, CAR maximum value was set at 35%.

Also for CFR, from the literature review the observed values ranged from 0% to 25% (Table 2). However, some of the data collected from the literature review were estimates of CFR derived from different populations (often representing high-risk groups) and source of information (mortality associated with the 2009 pandemic influenza A(H1N1) was estimated 15 times higher than reported laboratory-confirmed deaths) [40]. Moreover, when considering the influenza A(H5N1) avian influenza virus: CFR estimates reported by WHO for the ongoing outbreak is around 60% [41], even if, findings from a study based on surveillance and seroprevalence data published in 2008, reports estimates ranging from 14 to 33% [42]. For this reason we set the maximum level of the CFR at 2.5%, as most of values from recent pandemics ranged from 0.01 to 2.5% [13,14,32] (Table 3).

HAR depends on the level of virulence of the pandemic virus. However, its estimation may be affected by access to healthcare, proportion of chronic medical conditions in the population, pregnancy, and the virus characteristics (e.g. the level of pre-existing immunity, and pathogenicity of the virus itself). In our literature

**FIGURE 2**

Six possible scenarios identified by a combination of the selected parameters, study on pandemic influenza scenarios in Europe

**A**

Type of parameters	Parameters	Scenario 'seasonal-like'			
Transmission	CAR (%)	0–5	5–10	10–25	25–35
Virulence	CFR (%)	0–0.01	0.01–0.05	0.05–0.8	0.8–2.5
Use of medical resources	HAR (%)	0–0.02	0.02–0.2	0.2–2	2–4
	ICAR (%)	0–0.01	0.01–2.5	2.5–5	5–35

**B**

Type of parameters	Parameters	Scenario '2009 pandemic-like'			
Transmission	CAR (%)	0–5	5–10	10–25	25–35
Virulence	CFR (%)	0–0.01	0.01–0.05	0.05–0.8	0.8–2.5
Use of medical resources	HAR (%)	0–0.02	0.02–0.2	0.2–2	2–4
	ICAR (%)	0–0.01	0.01–2.5	2.5–5	5–35

**C**

Type of parameters	Parameters	Scenario 'community risk, low virulence'			
Transmission	CAR (%)	0–5	5–10	10–25	25–35
Virulence	CFR (%)	0–0.01	0.01–0.05	0.05–0.8	0.8–2.5
Use of medical resources	HAR (%)	0–0.02	0.02–0.2	0.2–2	2–4
	ICAR (%)	0–0.01	0.01–2.5	2.5–5	5–35

**D**

Type of parameters	Parameters	Scenario 'community risk, high virulence'			
Transmission	CAR (%)	0–5	5–10	10–25	25–35
Virulence	CFR (%)	0–0.01	0.01–0.05	0.05–0.8	0.8–2.5
Use of medical resources	HAR (%)	0–0.02	0.02–0.2	0.2–2	2–4
	ICAR (%)	0–0.01	0.01–2.5	2.5–5	5–35

**E**

Type of parameters	Parameters	Scenario 'high-risk groups/age groups'			
Transmission	CAR (%)	0–5	5–10	10–25	25–35
Virulence	CFR (%)	0–0.01	0.01–0.05	0.05–0.8	0.8–2.5
Use of medical resources	HAR (%)	0–0.02	0.02–0.2	0.2–2	2–4
	ICAR (%)	0–0.01	0.01–2.5	2.5–5	5–35

**F**

Type of parameters	Parameters	Scenario 'major event'			
Transmission	CAR (%)	0–5	5–10	10–25	25–35
Virulence	CFR (%)	0–0.01	0.01–0.05	0.05–0.8	0.8–2.5
Use of medical resources	HAR (%)	0–0.02	0.02–0.2	0.2–2	2–4
	ICAR (%)	0–0.01	0.01–2.5	2.5–5	5–35

CAR: clinical attack rate; CFR: case fatality rate; HAR: hospital admission rate; ICAR: intensive care admission rate.

The values of the parameters defining scenarios are highlighted in grey.

review we obtained values ranging from 0 to 27.5%. As the extreme value refer to pandemic 1918/19 in the US Army Camps, according to the opinions of the panel of experts set the maximum value to 4% as this value was collected in the general population [5].

For ICAR, it ranged from 0 to 35% in the literature review, and we considered the maximum of 35% as 'reasonable worst case' given that it was derived from an accurate evaluation of laboratory-confirmed influenza hospitalised cases conducted in the US [43].

Based on the above described ranges of values, it is possible to define 256 different scenarios. Among these, we selected six reasonable scenarios, according to the opinion of the panel of experts (Figure 2).

In detail, scenario A represents a 'seasonal-like' influenza outbreak; scenario B describes a situation in which the virus is quite diffusive, with an important HAR and a low virulence and ICAR, similar to the 2009 pandemic. The high HAR in scenario B could also represent high-risk groups (e.g. elderly, individuals with underlying conditions). Scenario C and D represent a situation in which the CAR is high with a low and a high virulence, respectively. Moreover, since the scenarios described above do not take into account the age profile of the population and the proportion of individuals

with chronic conditions, we consider a reasonable solution to retain scenario E and F that represent the worst case scenarios for at-risk groups.

## Discussion

In our study we defined a set of scenarios that may be useful for pandemic planning. We used the combination of four severity profiles of four epidemiological parameters to identify 256 possible scenarios that can be adapted over time and are far from the classic scenarios structure used for pandemic plans up to the 2009 influenza pandemic [1]. Among the scenarios identified, on the basis of a literature review and of the opinion of the panel of experts, we selected the six most likely scenarios that synthesise the possible effect of an influenza outbreak with different characteristics (from a seasonal-like to a major event).

Historically, influenza pandemic planning has been based on an assessment of the 'reasonable worst case', derived from previous influenza seasons and pandemics in the 20th century, and thus has shown not to be appropriate during a moderate event, such as the 2009 pandemic [44]. Other experiences reported a modelling approach using a combination of indicators leading to a qualitative assessment in three levels (i.e. mild, moderate and severe) [5]; that approach was considered not to be specific enough to guide

interventions [6]. Moreover, mathematical modelling based on preliminary epidemiological data is useful in defining the impact and the mitigation measures to be implemented during a pandemic. However, these models are strongly affected by the epidemiological parameters used and, even if they are able to explore a wide range of values, they need a specific set of scenarios to produce reliable results. For this reason, the use of scenarios in pandemic planning is crucial.

In our literature review, most of the selected articles and documents were observational studies, mathematical simulations, or reviews. Information referring to different world regions, different population subgroups and different influenza pandemics (mostly the 2009 influenza pandemic) over 100 years-period made comparison of results difficult. In fact, our results showed that most of the parameters values vary a lot between different countries and in different pandemics. For example, mortality rates often vary by age: age-specific mortality rates for 1957/58 and 1968/69 show a U-shaped pattern with a slightly increased CFR in the very young and an increasing one with older age [45]. On the other hand, during the 1918 pandemic, a higher mortality rate was observed in young adults followed by lower rates in other age groups [35]. Moreover, variation in epidemiological parameters could also reflect differences in the surveillance systems (e.g. in case of different case definitions, time lag between influenza confirmation and death, etc.) and diagnostic methods. This heterogeneous information presented in the documents did not allow us to use parts of the data (e.g. the absolute number of deaths was neglected where the corresponding denominator to calculate CFR was missing). It should also be noted that we did not consider age groups and the proportion of people with other underlying conditions that are strictly related to the vulnerability of the population to a pandemic virus [6]. Finally, estimates for the 2009/10 pandemic are likely to change as further data and studies become available after the literature review was conducted (December 2011).

The experience of the 2009 influenza pandemic showed that the EU countries had prepared for a pandemic of high severity but appeared unable to adapt their national and subnational responses adequately to a more moderate event. Knowledge of past pandemics is of substantial help when planning for a future one [46] and indeed the epidemiological aspects of the three 20th century influenza pandemics (1918/20, 1957/58, 1968/69) are of outstanding importance. However, modelling studies based on epidemiological parameters collected during the 20th century pandemics overestimated the impact of the 2009/10 pandemic [8]. Furthermore, society has undergone major changes since 1918 (the scenario on which most pandemic plans and models before and during the 2009 pandemic have been based) and even since 1968, with an increased availability of ICUs and clinical countermeasures (such as vaccines, antivirals, etc.).

Thus, in June 2013, the WHO published the 'Pandemic Influenza Risk Management' [8]. The approach taken in this document introduces a risk-based approach to pandemic influenza risk management and encourages countries to develop flexible plans, and to conduct risk assessments in order to prioritise the development of risk management programmes tailored to the hazards present. Our results are in line with the 'WHO Pandemic Influenza Risk Management' [8] and provide a description of possible scenarios of pandemic influenza considering key epidemiological parameters. The described scenarios allow severity assessments and provide the basis for developing flexible risk management plans over the course of a pandemic.

In the context of the FLURESP Project, the proposed scenarios have been used to select potential response strategies (clustered and ranked according to performance and efficiency using a multi-criteria analysis) in order to conduct cost-effectiveness evaluations to compare cost and performance of response strategies for each proposed scenario.

Our study, although not based on a standardised procedure, is supported by an extensive literature review and suggestions derived from a panel of experts.

In conclusion, our study provides an original template to categorise human influenza pandemic scenarios, useful for pandemic planning. Before using its outcomes, limitations should be taken into account by public health authorities dealing with pandemic planning. This study is the first step of the FLURESP project, whose objective is to define adequate public health responses and measures according to each scenario presented in this paper and to compare performance and cost-effectiveness of such measures.

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### Conflicts of interest

None declared.

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### Authors' contributions

The work presented here was carried out in collaboration between all authors. C.N. M.F. and C.R. contributed to the data collection, performed the analysis and drafted the manuscript. C.N., M.F., C.R., A.Bo., S.Bo., M.B., J.O., J.M.C., L.N., P.G., A.P., C.L. and C.G. interpreted the results. S.Br., A.N. and P.P. contributed to the methodological approach. A.Be. conceived the overall study aims and design. All authors have contributed to, seen and approved the manuscript.

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